

Senior Thesis

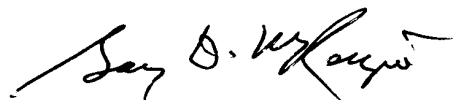
**Testing For Variations in Radon Soil Gas
Emissions Over Glacial Till
in Union County, Ohio**

**by
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1990**

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Approved by:

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Abstract

Many recent studies in Ohio on radon in glacial deposits have concluded that substrate characteristics (which includes both sediment and the underlying bedrock) have a primary influence on detected levels of radon soil gas. Throughout Ohio, till deposited over shale, particularly the Ohio Shale, produces consistently high levels of radon due to its high uranium content available to circulating groundwater. However, in till overlying limestone or sandstone, factors other than bedrock become more important influences on radon levels.

The bedrock of Union County, Ohio consists mostly of limestone and is covered by glacial deposits of variable thickness. A study of radon soil gas emissions in Union County was done for this thesis to get a better understanding of the effects of variable glacial till characteristics on detected soil gas levels. The results of this study indicate that permeability, proximity to the watertable, and the amount of uranium-bearing material in the till are the most important factors which influence variations of radon soil gas in this county. These findings also suggest that radon is not an effective tool to locate fractures and areas of high permeability in glacial deposits.

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Introduction

Purpose of Study

The purpose of this study is to determine how variations in permeability, depth to bedrock, depth to the watertable, extent of fracturing, and composition of glacial deposits influence the amount of radon being emitted from the soil at different sites within Union County. The results may suggest that radon can be used as a locating tool or an indicator of certain geological characteristics. More specifically, radon may provide aquifer recharge information to local hydrologic studies.

Characteristics of Radon

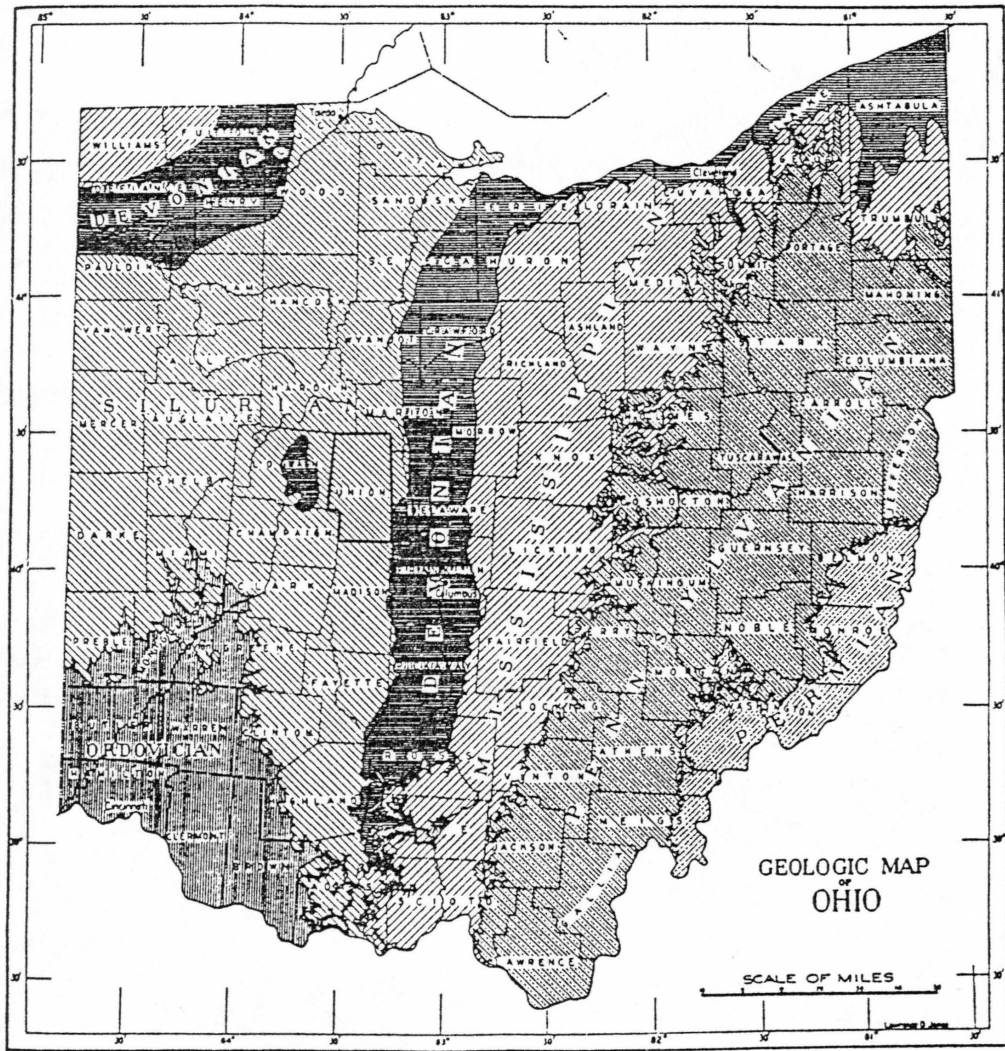
Radon gas is a member of the radioactive decay series of uranium to lead. The primary sources of uranium are granitic igneous rocks and sediments derived from these rocks (Smith and Mapes, 1989). Oxidized uranium-bearing minerals can migrate in groundwater and precipitate into sedimentary rocks upon reaching a reducing environment (which is characteristic of dark shales). Once produced from its parent material, radium, radon gas is easily absorbed into groundwater, or free to migrate through pore spaces or fractures by diffusion (Hinkel, 1989). Radon's (Rn-222) migration distance is limited by its half-life, which is 3.82 days. Within 13 days, the decay will be 90% complete (Darr, 1990). Therefore, unless radon is moving through a very permeable material (i.e. alluvium), a sufficient supply of radium must be near the surface in order for radon to be emitted as a soil gas.

Geology of Union County

During the Pleistocene, Illinoian and Wisconsinan ice sheets left glacial deposits of till, sand and gravel ranging from 12 to 48 feet in thickness (Wilson, 1987) over Silurian-age carbonate bedrock in what is now Union County, Ohio. Only Wisconsinan till is exposed here (Waters and Matanzo, 1975). Two end moraines, the Powell and the Broadway, dissect the county in a general east-west direction. Figures 1 and 2 are geologic maps of bedrock and glacial deposits in Ohio. The glacial deposits within the county are not homogeneous. Till varies mainly in texture and composition and has a high percentage of calcareous material derived from the local bedrock (Waters and Matanzo, 1975). Yet, the till north of the Powell moraine is generally clay rich, and is characteristically silty to the south. At least three type morphologies of till (end moraine, ground moraine and alluvium) were deposited in Union County, and each of these morphologies characterize at least one of the sites tested in this study.

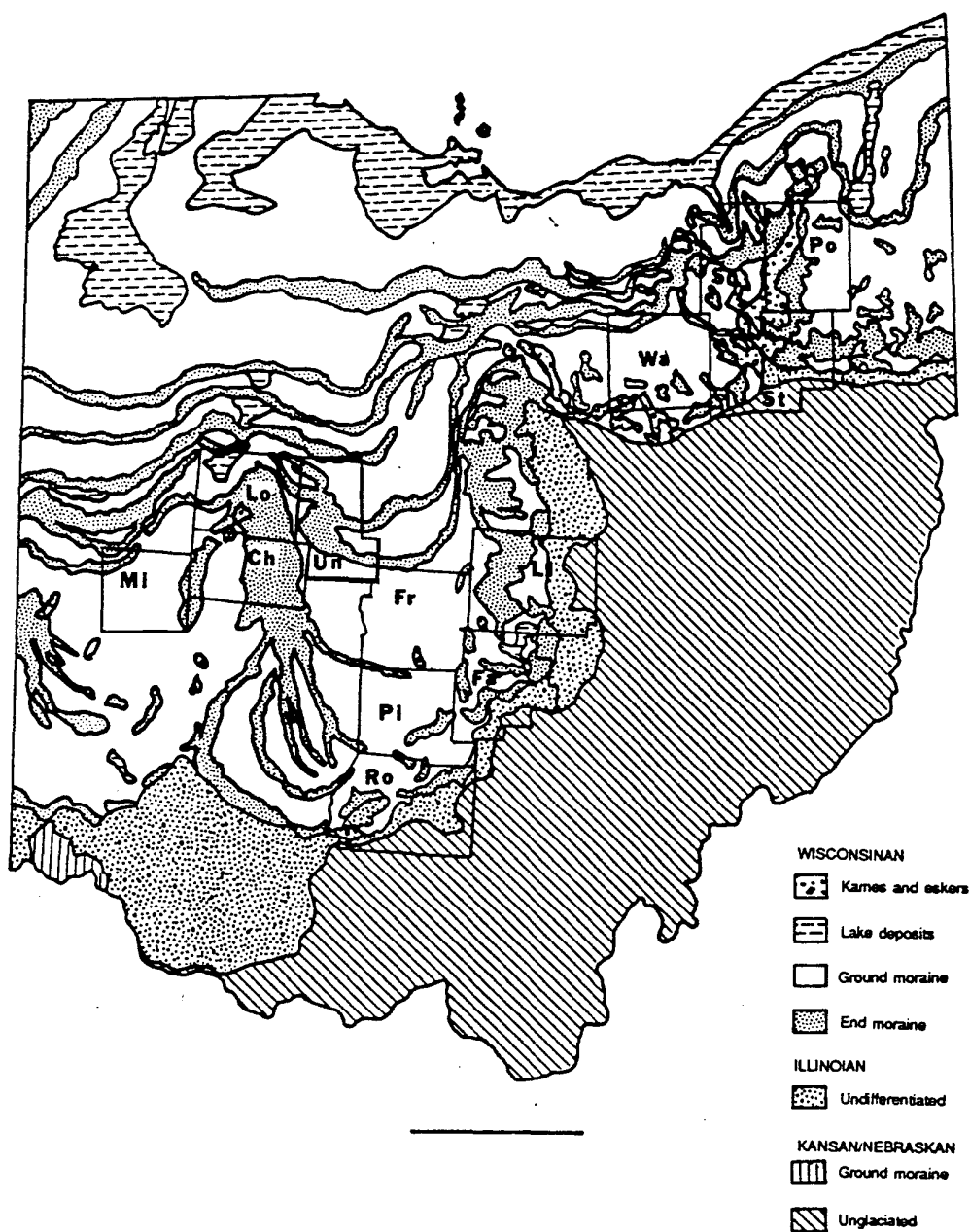
Important to this study is the fact that the Pleistocene ice sheets advanced from Canada, bringing with them granitic material, and depositing this uranium-bearing granite within the till of this county. Although Strobel and Faure (1987) stated that there is an exponential decrease in the percent of one type composition as a glacier advances onto a different bedrock lithology, they also described Union County as having a general abundance of 4% granitic clasts. Since limestone and dolomite are considered the least radioactive sedimentary rocks (Darr, 1990), the existence of granitic material is probably the primary source of radon within the county.

Also important to this study is the proximity of Ohio Shale in adjacent counties to the east (Figure 3). Since the advancing glaciers generally came from the northeast, uranium-bearing shale may have been incorporated into the glacial till deposited in the east of Union County.



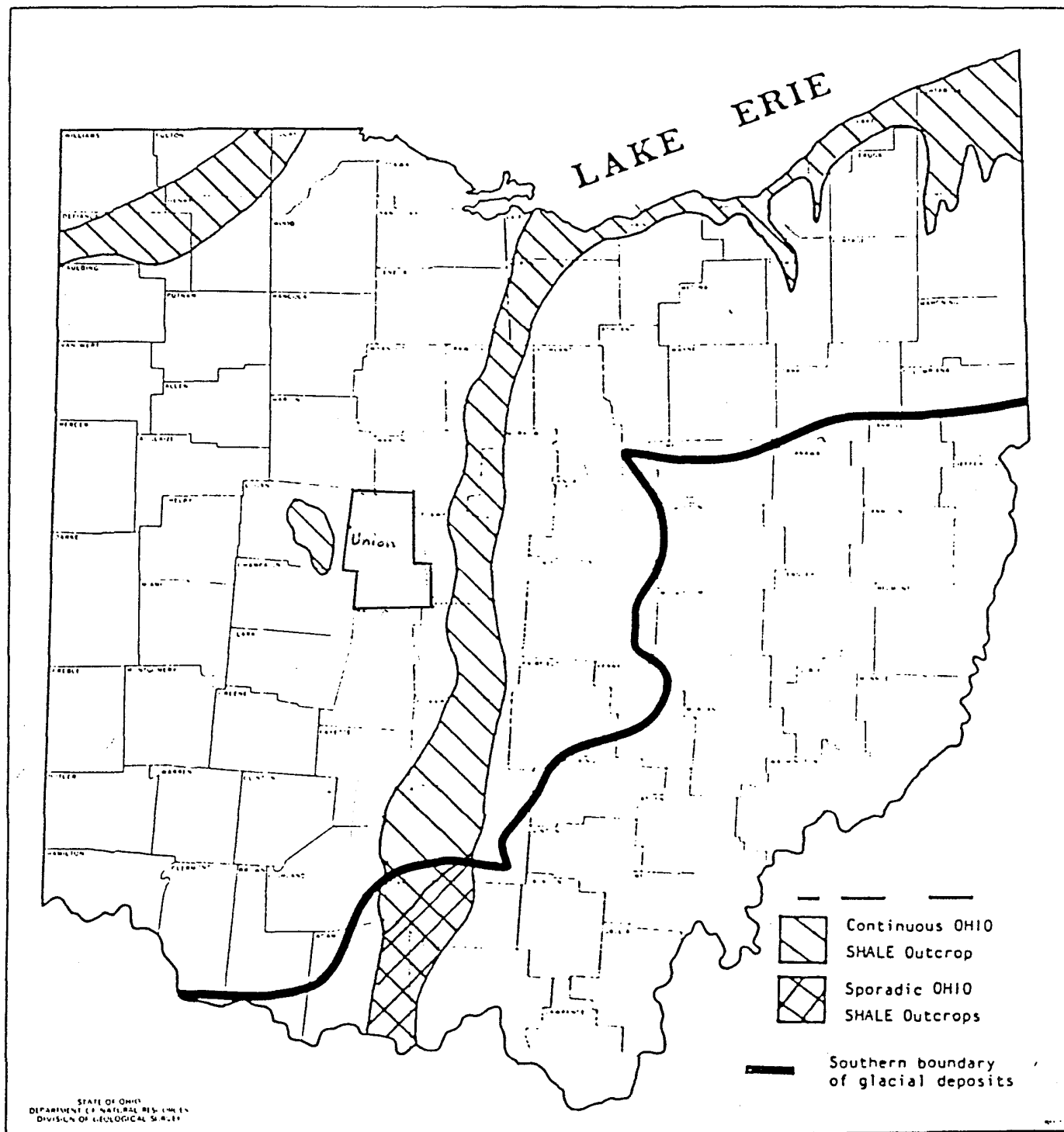
Geologic Map of Ohio showing counties and ages of the bedrock. (from Lamborn et al., 1938)

Figure 1



Generalized glacial map showing the counties included in the Smith and Mapes study (1989). (Ch)=Champaign, (Fa)=Fairfield, (Fr)=Franklin, (Li)=Licking, (Lo)=Logan, (Mi)=Miami, (Pi)=Pickaway, (Po)=Portage, (Ro)=Ross, (St)=Stark, (Su)=Summit, (Un)=Union, (Wa)=Wayne (modified from Goldthwait et al., 1979).

Figure 2



Distribution of Devonian (Ohio Shale) Black Shales (from Harrell and Kumar, 1988).

Figure 3

Permeability

Recent studies done on radon in Ohio by Smith and Mapes (1989), Darr (1990) and Hinkel (1989) have concluded that an area of glacial till with a high permeability is more likely to produce higher radon soil gas levels than an area of lesser permeability. Radon's ability to migrate depends on the effective permeability of the till. The greater the permeability or fracturing, the farther a given sample can migrate before decaying (Hinkel, 1989). The extent of fracturing and composition of glacial deposits are major components of the material's permeability.

Among the sites tested in this study, three types of glacial till were investigated. According to the Smith and Mapes (1989) study, outwash and alluvium is most permeable, and consists of sorted sand and gravel. End moraines have an intermediate permeability, consisting of unsorted and unstratified sand, silt, clay, pebbles, cobbles, and boulders. Ground moraines are the least permeable of the three types and have a composition similar to end moraines.

Permeability of glacial deposits controls recharge to bedrock aquifers in glaciated areas of the United States (clay rich-tills are usually considered aquitards). Freeze and Cherry (1979) state that the bulk hydraulic conductivity of fractured till is 1 to 3 orders of magnitude larger than values of unfractured samples (determined by laboratory tests and field studies). Therefore, radon should be a feasible tool for looking for high permeability in glacial deposits. In areas of similar lithology (i. e. clay-rich tills) and mineral composition, increases in radon may indicate fractures in tills and have potential to provide recharge information to local hydrologic studies.

Depth to Watertable

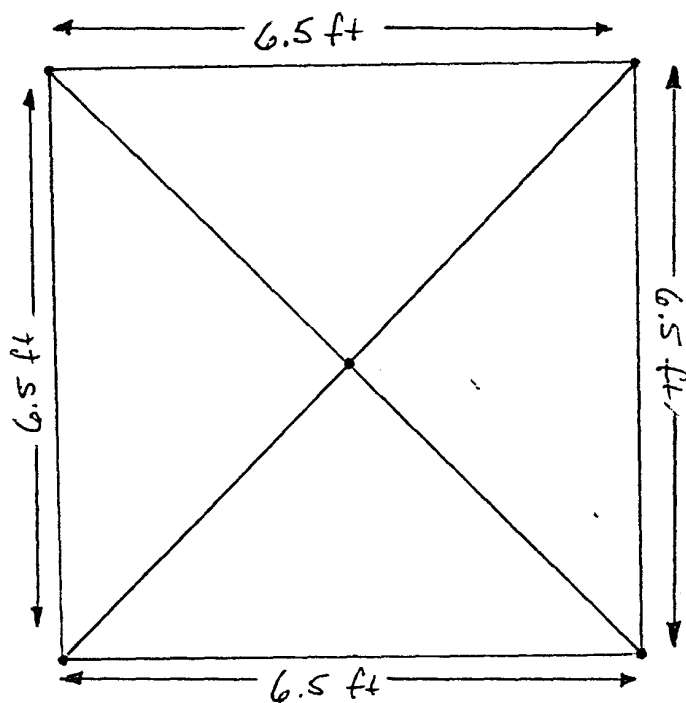
Depth to the watertable varies from 7 to 48 feet among the test sites in this study. Ogden and others (1987) point out that a fluctuating watertable can cause a pumping action that aids in the upward migration of radon gas. This pumping action should have a more substantial effect on radon soil gas levels at sites closest to the watertable. Well logs of Union County from the Ohio Division of Natural Resources Groundwater Division were used to approximate the depth to watertable at each site.

Methods

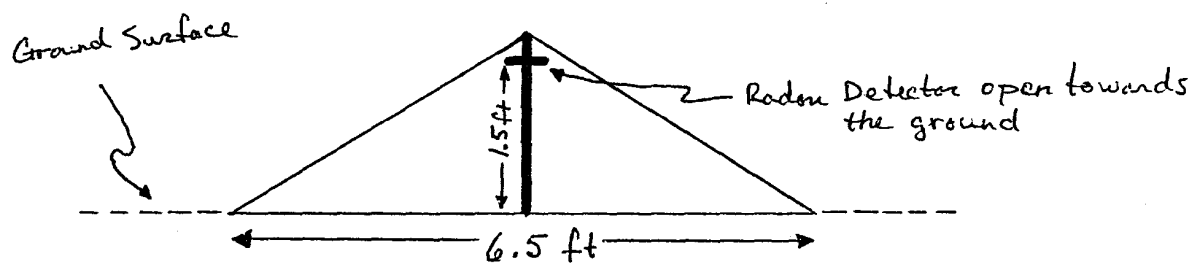
In order to get radon soil gas measurements, tents with radon detectors were set up on the ground surface at each of the seven sites. Each tent was equipped with an activated charcoal canister (detector) obtained from the Executive Home Services Radon Testing Laboratory. The tents were made of square sheets of plastic (staked down at the four corners) and the canisters were fastened to the center pole. Nearby logs and rocks were used to seal the plastic to the ground around the perimeter. Each tent covered an area of approximately 42 sq ft. Diagrams of the tents are shown in figure 4.

The testing period for each site was approximately 72 hours, after which the canisters were resealed and brought back to the Radon Testing Lab for analysis. Since all the tests were conducted simultaneously, changing weather conditions should have had a uniform affect on each test site.

The seven test sites were chosen to represent a variety of characteristics of the glacial deposits in Union County. Each site has a unique combination of permeability,



Tent Diagrams - view from above



Cross Section View

Figure 4

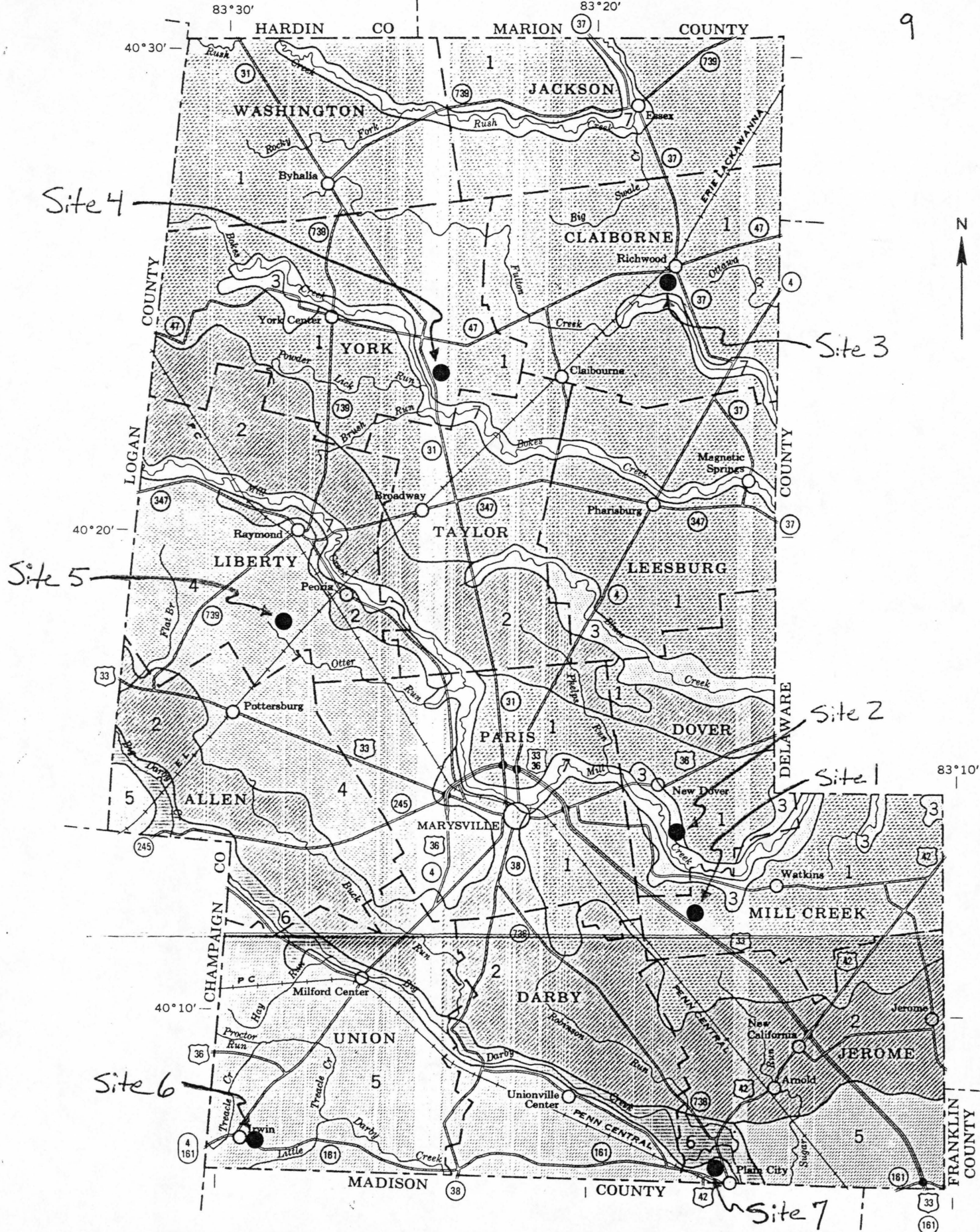


Figure 5 (Test sites)

composition, fracturing and depth to the watertable, which allows for comparisons to be made among the sites. Figure 5 shows the seven test site locations.

Results of Study

Table 1 describes the characteristics of each site and the amount of radon detected by the activated charcoal canisters. Sites 1 and 5 had more than one tent, and their measured radon levels were averaged. Depth to bedrock data was obtained from figure 6. Mike Strobel, of the USGS, supplied information on fractures at the sites. Radon is measured in picoCuries per liter (pCi / l).

Discussion of Results

The radon soil gas measurements listed in Table 1 range from 1.4 to 22.1 pCi / l for the seven sites. These soil gas variations must be due to the unique geological characteristics of each site. The sites will be compared relative to each other.

Site 1

This site has a moderate radon concentration of 10.6 pCi / l. Depth to the water table is also moderate. The geology is a clay-rich ground moraine which characteristically has a low permeability and should produce low radon levels. A fracture network within the till may be responsible for the moderate level of radon. Also, this site may be affected by its proximity to the Ohio Shale.

Table 1

Site	Radon Concentration	Morphology	Lithology	Depth to Watertable	Depth to Bedrock	Fractures
1	10.6 pCi/l	Ground Moraine	Clay	24 feet	40 feet	Yes
2	22.1 pCi/l	Alluvium	Silty Clay	18 feet	70 feet	No
3	5.8 pCi/l	Ground Moraine	Clay	07 feet	20 feet	Yes
4	9.7 pCi/l	Ground Moraine	Clay	14 feet	35 feet	Yes
5	2.0 pCi/l	End Moraine	Clay	48 feet	80 feet	Yes
6	1.4 pCi/l	Ground Moraine	Silty Clay	12 feet	210 feet	No
7	19.0 pCi/l	Ground Moraine	Silty Clay	15 feet	110 feet	No

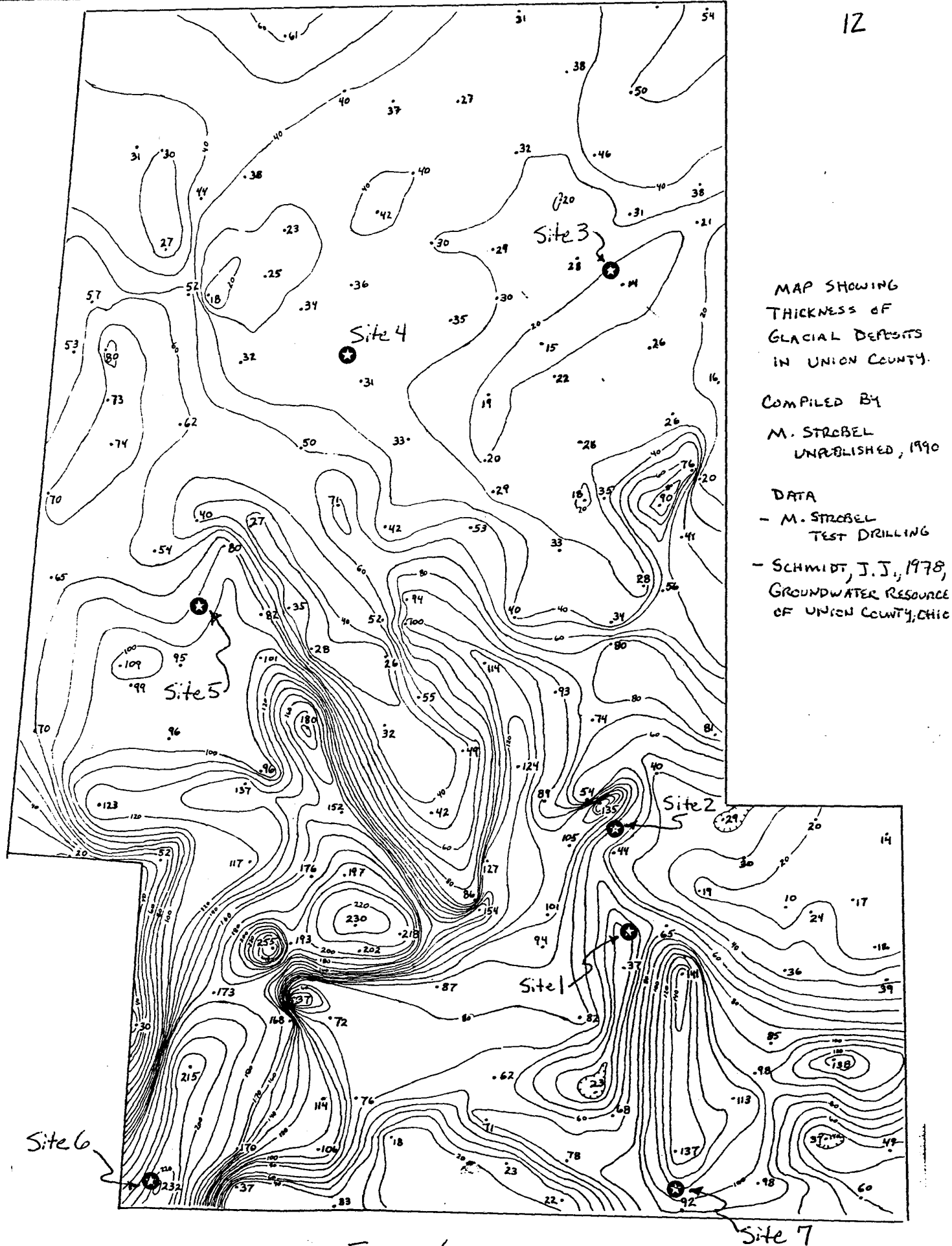


Figure 6

Site 2

This site has the highest radon concentration of 22.1 pCi / l. Since depth to the watertable is moderate, the high permeability of the silty clay alluvium is probably responsible for the high reading.

Site 3

This site has a low radon concentration of 5.8 pCi / l, and is the closest to the water table. The low reading may indicate that the clay-rich ground moraine has a very low permeability and the extent of fractures is minimal. It may also suggest that the pumping action of the watertable and the existence of fractures are minor influences on radon soil gas emissions.

Site 4

This site has a moderate radon concentration of 9.7 pCi / l. With respect to site 1, it is geologically similar, and closer to the watertable. The slightly lower radon level of this site may be due to the fact that it is farther away from the Ohio Shale.

Site 5

This site has a very low radon concentration of 2.0 pCi / l. A clay-rich end moraine characteristically has a higher permeability (thus, higher radon levels) than clay-rich ground moraines. But, this site is also furthest from the watertable (48 ft), which may be responsible for its low reading. Radon from groundwater would undergo extensive decay moving through this distance. Also, the extent of fractures may be minimal, or do not penetrate very deeply, or have no influence at all.

Site 6

This site has the lowest radon concentration of 1.4 pCi / l, and is close to the watertable (12 ft). The ground moraine here consists of silty clay, which has a higher permeability than a clay-rich moraine and should produce higher radon levels. The lack of fractures may be the primary influence on the low reading. The depth to bedrock (210 ft) may be another factor, but a reason for this is uncertain. Also, this site is the farthest from the Ohio Shale.

Site 7

This site has a very high radon concentration of 19.0 pCi / l and a moderate distance to the watertable. The geology is very similar to site 6, yet the radon level is very different. The reason for this may be due to the fact that site 7 is closest to the Ohio Shale.

Conclusion

Since the bedrock is relatively uniform throughout Union County (Silurian carbonates), some general conclusions can be drawn from this study concerning the relationship between radon and glacial deposits. The results indicate that the permeability of glacial deposits, which is a function of grain size and fracturing, is the primary influence on radon soil gas emissions. This appears to be evident at site 2, where the highly permeable alluvium has produced the highest radon level among all the sites. Site 5 (48 ft to watertable) tends to support the assumption that increasing the distance to the watertable may diminish the effect of fluctuations, and therefore decrease the amount of radon escaping from the soil. The drastic difference of detected radon between sites 6 and 7 suggests that the percentage of uranium-bearing Ohio Shale incorporated within the till decreases from east to west across the county. Concerning depth to bedrock, no conclusions can be made from this study. Darr (1990) and Hinkel (1989) state that the

influence of till thickness beyond ten feet was negligible in their study areas. Future studies should focus on one of these aspects of glacial deposits at a time, having it (i. e. permeability, depth to watertable) be the only variable in the study.

The ground moraine sites allow for a general comparison of fractured and unfractured till. Among the sites located on ground morains, the average radon level over fractured till is 8.7 pCi / l, and 10.2 pCi / l for unfractured till. On the basis of this, no conclusions can be made concerning the relationship between fractured till and radon. This study found that fractures probably have little or no influence on radon soil gas emissions in glacial deposits. More specific studies on fractures (in which the extent of fracturing is the only variable characteristic of the till) must be done to test the assumption that the existence of fractures will increase radon soil gas by increasing permeability.

Acknowledgement

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